1996. The Journal of Arachnology 24:262–264

RESEARCH NOTE

INTERPOPULATION AND INTERSEXUAL VARIATION IN PECTINE TOOTH COUNTS IN *CENTRUROIDES VITTATUS* (SCORPIONIDA, BUTHIDAE)

The pectines of scorpions are comblike structures whose primary functions seem to be as contact chemoreceptors and mechanoreceptors (Hjelle 1990). These appendages are unique to scorpions and appear important in such activities as substrate recognition (Polis & Sissom 1990) and mate identification (Gaffin & Brownell 1992). A pectine consists of two pectens, or combs, each of which contains a variable number of pectinal teeth. These tooth counts, along with various other morphological aspects of the pectines, have been utilized as taxonomic characters, both to help separate genera or species and to distinguish between sexes within a species. In the latter situation, pectine tooth counts for males are generally higher than for females. In some cases (e.g., some *Paruroctonus* Werner 1934), male and female counts do not overlap (Sissom & Francke 1981); however, in many species there exists considerable overlap and sexual variation is seen as differences in the modal or average tooth number per comb. To date, there has been little attempt to determine statistically whether pectine tooth counts are, in fact, sexually dimorphic. Additionally, only one study of which I am aware [of *Uroctonus mordax* Thorell 1876 (Hjelle 1972)] has examined specimens from various populations within a species' range to determine whether there exists interpopulation variation in this trait; such variation may make it difficult to use pectine tooth counts to help distinguish sexes or species. For the family Buthidae, pectine tooth counts have been shown to differ statistically between males and females, with males having larger counts, for two litters of *Centruroides gracilis* (Latreille 1804) (Francke & Jones 1982), while no statistically significant intersexual variation was seen in *Tityus cambridgei* Pocock 1897 (Lourenço 1981). In this note I examine both sexual and interpopulation differences in pectine tooth counts in the buthid scorpion *Centruroides vittatus* (Say 1821) from three populations within the state of Texas.

Centruroides vittatus is a commonly encountered scorpion throughout the south central plains of the United States west of the Mississippi River, and northern México (Shelley & Sissom 1995). The sexes in this scorpion can be easily distinguished by the much longer and thinner metasomal segments of the males. For this study, individuals were collected from three populations: (1) the Chandler Independence Creek Preserve of the Texas Nature Conservancy, located at the confluence of Independence Creek and the Pecos River approximately 37 km south of Sheffield, Terrell County in west Texas; (2) Kickapoo Caverns State Park, located on the Kinney County-Edwards County border in south-central Texas; and (3) Lyndon B. Johnson National Grasslands, north of Decatur, Wise County in north-central Texas. Females from these populations are known to vary in overall body size as well as some life history traits (Brown & Formanowicz 1995). A total of 375 *C. vittatus* (213 females, 162 males; see Table 1) was collected in November 1991 (Kickapoo males only), April–June 1992 (males only), March–October 1993, April–July 1994, and July 1995 (Kickapoo males only). Scorpions were either immediately preserved (1991 and 1992 samples) or housed as described in Brown & Formanowicz (1995). Upon death or preservation of an individual, the number of teeth on each comb of the pectines was counted using an American Optical™ dissecting microscope. The sum of the tooth counts for both combs was used for all analyses. Analyses identical to those described below were performed separately for either the right or left comb count, resulting in slight changes in the calculated statistics

Table 1.—Pectine tooth count variation between sexes and among populations in the scorpion *Centruroides vittatus*. Counts are the sum of teeth on both left and right combs. Values given are means ± SD, range, and sample size *n*. *H* is a result from a Kruskal-Wallace ANOVA among populations for either males or females. *U* is a result from a Mann-Whitney *U*-test between sexes, performed within each population.

	Independence Creek	Kickapoo	Decatur	*H*	*P*
Males	51.7 ± 1.78	48.9 ± 2.01	47.5 ± 1.75	83.6	<0.0001
range	48–55	43–53	43–52		
n	57	54	51		
Females	47.8 ± 1.59	45.4 ± 1.77	43.5 ± 2.45	100.1	<0.0001
range	41–52	41–50	37–48		
n	64	88	61		
U	185	477.5	221		
P	<0.0001	<0.0001	<0.0001		

and *P*-values but no change in the overall results (these values are therefore not reported). Within each population, tooth count differences between males and females were examined using a Mann-Whitney *U*-test (Sokal & Rohlf 1981). Among population variation in tooth counts for both males and females was examined with a Kruskal-Wallace ANOVA (Sokal & Rohlf 1981). In the above tests, non-parametric tests were performed because of non-normality of some of the data. Since pectine tooth counts in *C. vittatus* do not change as an individual grows (unpubl. data), and because there were no significant differences among years for either sex from any population, data from all years were combined. All analyses were done using the STATISTICA computer package (StatSoft 1991).

For all three populations pectine tooth count was significantly greater in males than in females (Table 1). In addition, tooth counts differed significantly among populations for both males and females (Table 1). For both sexes, Independence Creek individuals had the greatest counts, followed by individuals from Kickapoo and then Decatur. A *post hoc* multiple comparison test (Daniel 1990) indicated that, for both males and females, counts were significantly different for all pairwise comparisons among populations.

Variation in pectine tooth counts also was found within individuals (Table 2). For each population, approximately half (47–55%) of the individuals had unequal numbers of teeth on each comb, with a maximum difference between combs of three. This result is similar to that found for *Centruroides gracilis*, where for two litters asymmetric and symmetric counts were equally frequent (Francke & Jones 1982). A *G*-test of independence (Sokal & Rohlf 1981) for each population indicated that sex did not influence whether individual scorpions had equal or unequal numbers of teeth per comb for Kickapoo ($G = 0.82$, $P = 0.37$) or Decatur ($G = 0.50$, $P = 0.48$), while the result was marginally significant for Indepen-

Table 2.—Within individual variation in pectine tooth counts in *Centruroides vittatus*. "Equal" indicates that both combs on an individual had the same number of teeth. "Unequal" indicates that the combs on an individual had unequal numbers of teeth. Numbers in parentheses indicate individuals that had the highest count on the left or right comb, respectively.

	Independence Creek		Kickapoo		Decatur	
	Females	Males	Females	Males	Females	Males
Equal	34	20	46	24	34	25
Unequal	30	37	42	30	27	26
	(9, 21)	(16, 21)	(14, 28)	(11, 19)	(10, 17)	(12, 14)

dence Creek ($G = 3.95$, $P = 0.047$), with males being more likely to have unequal counts. However, sex did influence which comb had more teeth. In females, the right comb was more likely than the left comb to have a greater tooth count (statistically significant for only Independence Creek and Kickapoo), while in males either comb was equally likely to have the greater tooth count [G-test for goodness of fit (Sokal & Rohlf 1981), for females—Independence Creek: $G = 5.63$, $P < 0.025$; Kickapoo: $G = 4.76$, $P < 0.025$; Decatur: $G = 1.84$, $P > 0.1$; and for males—Independence Creek: $G = 0.68$, $P > 0.1$; Kickapoo: $G = 2.16$, $P > 0.1$; Decatur: $G = 0.15$, $P > 0.5$].

These results indicate statistically that pectine tooth counts in *C. vittatus* are sexually dimorphic, and that variation in counts between combs of an individual is quite common, similar to results found in a smaller sample of the congener *C. gracilis* (Francke & Jones 1982). In addition, I have shown that variation in this trait can be observed among populations of a single species, as has been demonstrated for other traits such as body size or color patterns. This latter result illustrates the potential problems when using pectine tooth counts to distinguish sexes or species. As an example in *C. vittatus*, if a sample included only males from Independence Creek and females from Decatur, one would conclude that tooth counts were very dimorphic, with almost no overlap in the range of total tooth counts. Alternatively, if only females from Independence Creek and males from Decatur were available, one would conclude that pectine tooth counts were not sexually dimorphic, and in fact showed nearly complete overlap in total tooth counts. Both of these conclusions are potentially misleading, since an important source of variation (among populations) has not been considered.

ACKNOWLEDGMENTS

Paul Klawinski and Daniel Formanowicz provided reviews and assisted in collecting scorpions. I also thank John Davis, Dan O'Connell, Larry Shaffer, Josh Rose, Bill Jordan, Lara Gott, Jay Herman and Chris Amaya for help in the field. Dave Stewart and Mark Lockwood (Kickapoo Caverns) and Jobeth Holub and John Karges (Independence Creek) kindly allowed me to collect all the scorpions I needed and made us feel welcome during our stays. This research was supported in part by a grant from the Texas Chapter of The Nature Conservancy to D. R. Formanowicz, Jr. and was done under permits #15-92, #14-93 and #43-94 from Texas Parks and Wildlife Department. Voucher specimens have been deposited in the American Museum of Natural History, New York.

LITERATURE CITED

Brown, C.A. & D.R. Formanowicz, Jr. 1995. Variation in reproductive investment among and within populations of the scorpion *Centruroides vittatus*. Oecologia (Berlin), 103:140–147.

Daniel, W.W. 1990. Applied Nonparametric Statistics, 2nd ed. PWS-Kent, Boston.

Gaffin, D.D. & P.H. Brownell. 1992. Evidence of chemical signaling in the sand scorpion, *Paruroctonus mesaensis* (Scorpionida: Vaejovida). Ethology, 91:59–69.

Francke, O.F. & S.K. Jones. 1982. The life history of *Centruroides gracilis* (Scorpiones, Buthidae). J. Arachnol., 10:223–239.

Hjelle, J.T. 1972. Scorpions of the northern California coast ranges (Arachnida: Scorpionida). Occ. Papers California Acad. Sci., 92:1–59.

Hjelle, J.T. 1990. Anatomy and morphology. Pp. 9–63, *In* The Biology of Scorpions. (G.A. Polis, ed.). Stanford Univ. Press, Stanford, California.

Lourenço, W.R. 1981. Estudo da variabilidade do caráter número de dentes dos pentes nos escorpiões *Tityus cambridgei* Pocock, 1897, e *Rhopalurus laticauda* Thorell, 1876. Rev. Brasileira Biol., 41:545–548.

Polis, G.A. & W.D. Sissom. 1990. Life history. Pp. 161–223, *In* The Biology of Scorpions. (G.A. Polis, ed.). Stanford Univ. Press, Stanford, California.

Shelley, R.M. & W.D. Sissom. 1995. Distributions of the scorpions *Centruroides vittatus* (Say) and *Centruroides hentzi* (Banks) in the United States and Mexico (Scorpiones, Buthidae). J. Arachnol., 23:100–110.

Sissom, W.D. & O.F. Francke. 1981. Scorpions of the genus *Paruroctonus* from New Mexico and Texas (Scorpiones, Vaejovidae). J. Arachnol., 9:93–108.

Sokal, R.R. & F.J. Rohlf. 1981. Biometry, 2nd ed. Freeman, New York.

StatSoft. 1991. CSS: STATISTICA. StatSoft, Tulsa, Oklahoma.

Christopher A. Brown: Dept. of Biology, Box 19498, University of Texas at Arlington, Arlington, Texas 76019 USA

Manuscript received 4 December 1995, revised 15 June 1996.